Friction Stir Welding and Copper-Chromium Zirconium: a New Concept for the Design of the Sirius' High-Power Absorbers

G.V. Claudiano†, L.M. Volpe, Brazilian Synchrotron Light Laboratory (LNLS/CNPEM), 13083-970, Campinas, São Paulo, Brazil.
E.B. Fonseca, M.H.S. Silva, Brazilian Nanotechnology National Laboratory (LNNano/CNPEM), 13083-970, Campinas, São Paulo, Brazil.

† gabriel.claudiano@lnls.br

Abstract

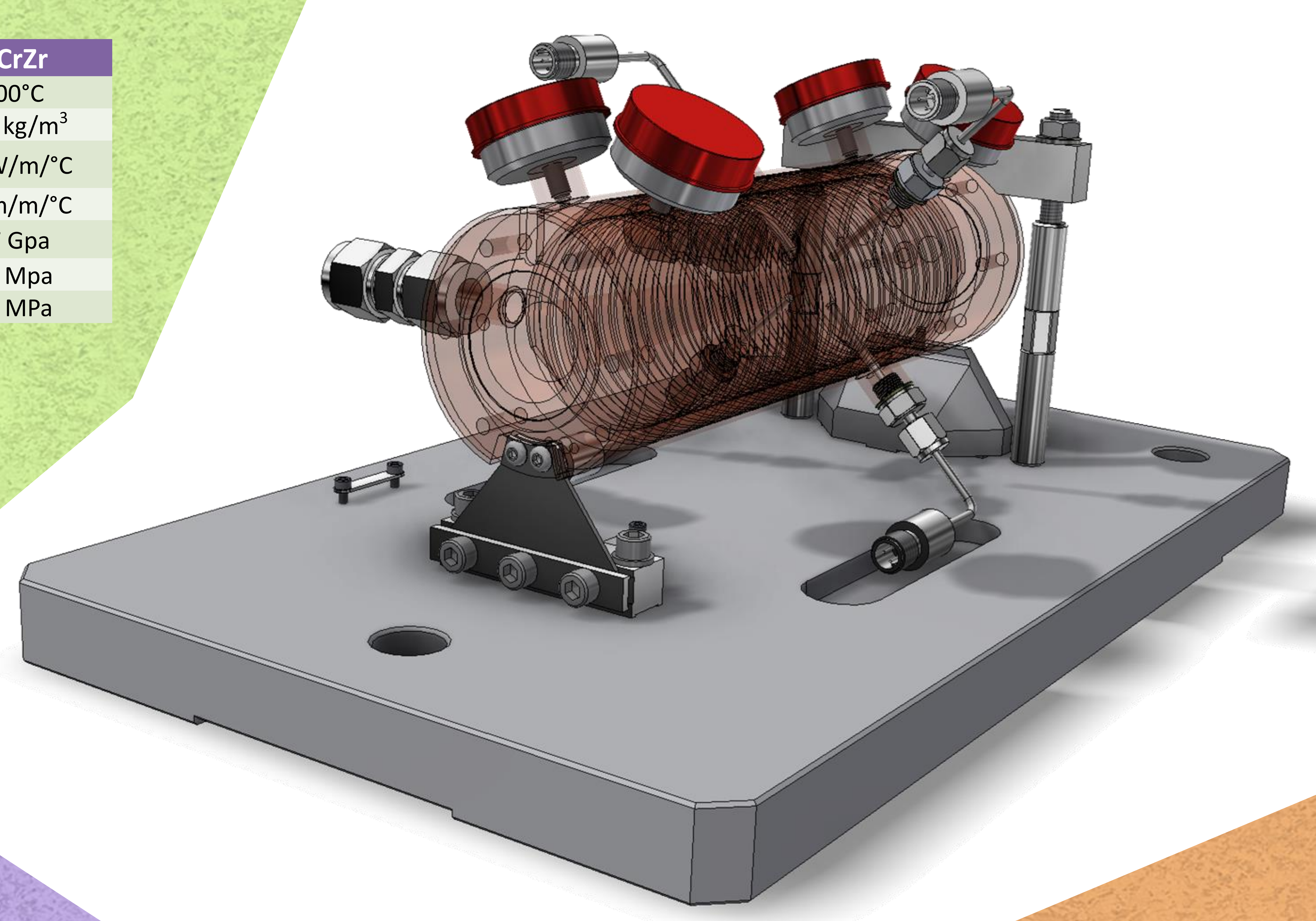
Sirius, the new Brazilian fourth-generation synchrotron light source, is currently under construction. Due to the high brilliance and low emittance of its source, the pho-ton beam on each undulator beamline can have power densities as high as 55 W/mrad². To protect the components downstream, the Front-End power absorbers need to manage this power in a limited space, but also having precision in alignment and being reliable all over their lifetime. To achieve this behavior, the selected alloy was the copper-chromium-zirconium (CuCrZr, commercially known as C18150) because of improved thermal and mechanical properties. In order to seal the vacuum chamber (path on which the cooling water flows), friction stir welding was the selected joining method. During the welding process, the material passes through a grain refinement process which results in a high-resistance joint. The manufacturing process could also result on a reduction of costs and lead times. Finally, it will be presented the optimizations done on the component, on its support and the characterizations done to validate the welded joint under vacuum and water pressure requirements.

Copper-Chromium-Zirconium (CuCrZr, C18150)

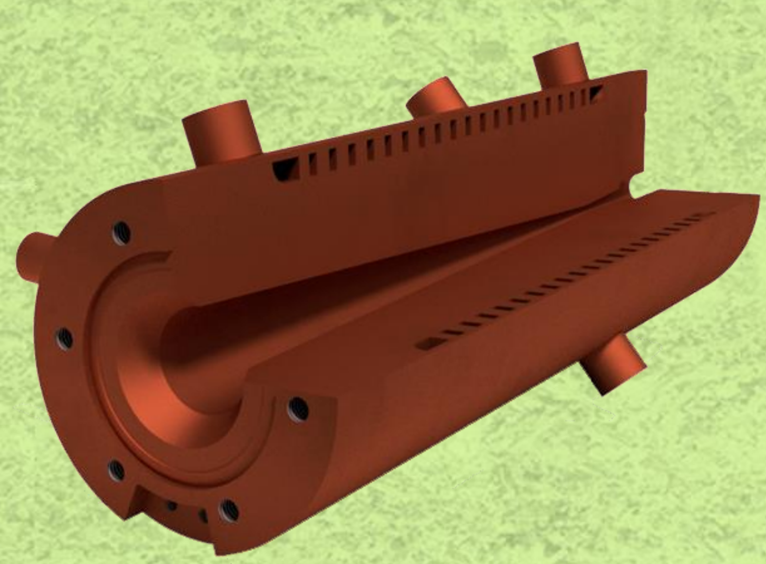
The design of Sirius' power absorbers (*i.e.* fixed mask, photon shutter and high-power slits) was optimized. One key chain was the use of CuCrZr instead of Glidcop. The main reasons were:

- it is cheaper and available on national market;
- its mechanical and thermal properties are alike the Glidcop (as seen in the table);
- it is vacuum compatible.

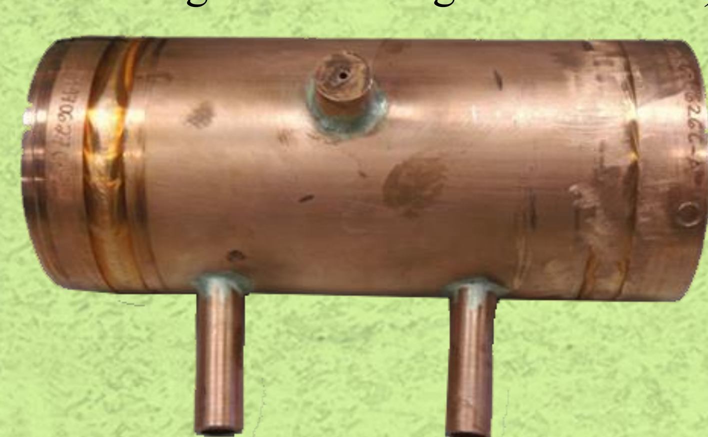
Property	Glidcop (Al-15)	CuCrZr
Melting Point	1083°C	1000°C
Density	8900 kg/m^3	8900 kg/m^3
Thermal Conductivity	365 W/m/°C	320 W/m/°C
CTE	16.6 μm/m/°C	17 μm/m/°C
Modulus of Elasticity	130 GPa	117 Gpa
Tensile Strength	393 MPa	420 Mpa
Yield Strength	324 MPa	400 MPa



Also, as CuCrZr is a precipitated-hardened alloys it is necessary not only to limit the temperatures during manufacturing of the component, but also during its operation in the beamline (a thermal cycle can efface the previous heat treatment, and along with recrystallization, result in lower yield and ultimate strength than the aged base metal).



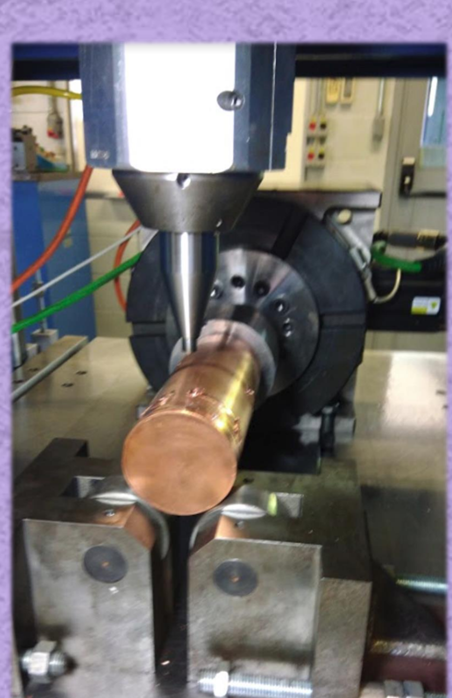
Three-quarters view of a component. It is possible to notice the water chamber and the flange machined on the CuCrZr bulk.



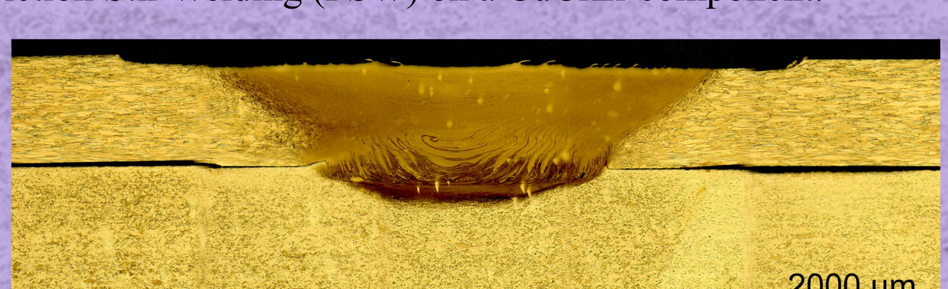
CuCrZr componente welded by FSW

Friction Stir Welding (FSW)

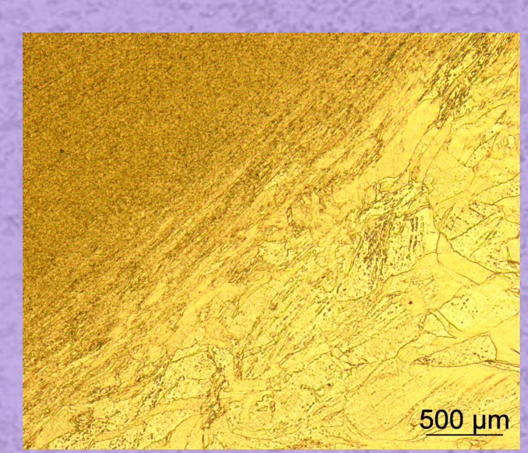
Due to their high thermal conductivity, copper and copper alloys are difficult to weld using conventional techniques (*i.e.* techniques that involve fusion). Differently from conventional processes, friction stir welding (FSW) is a solid-state joining technique capable of overcoming the problems related to welding of copper. FSW consists of a rotating non-consumable tool, which is inserted in the material and translates along the weld path to create a joint. The tool generates heat from friction and deformation. Since maximum temperatures lay below the melting point of the alloy, solidification-related phenomena are eliminated. Besides, FSW promotes grain refinement, thus improving mechanical performance.



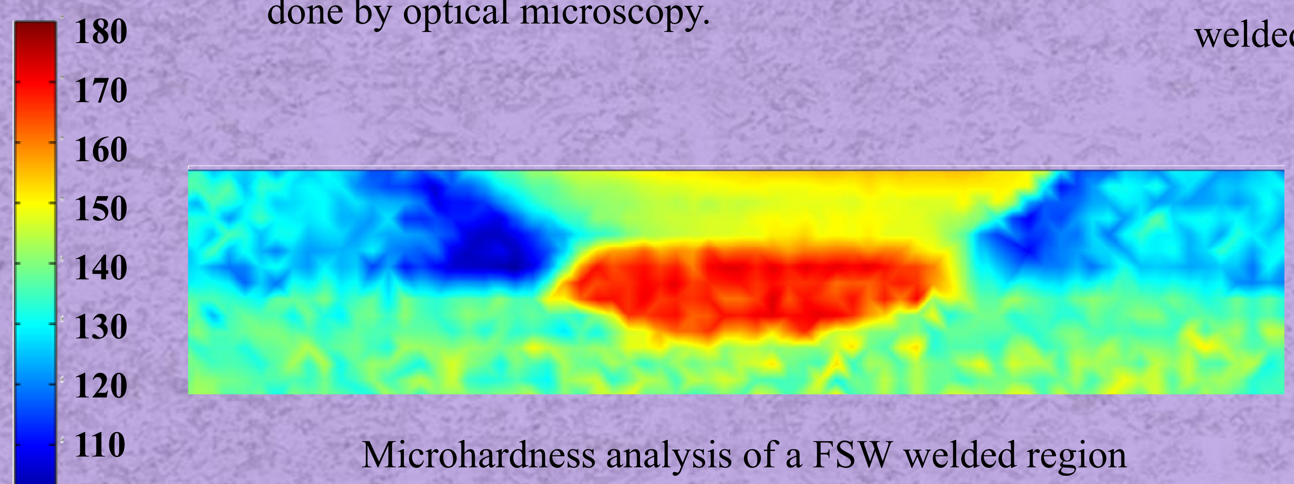
Friction Stir Welding (FSW) on a CuCrZr component.



Cross-section image of the welded region done by optical microscopy.



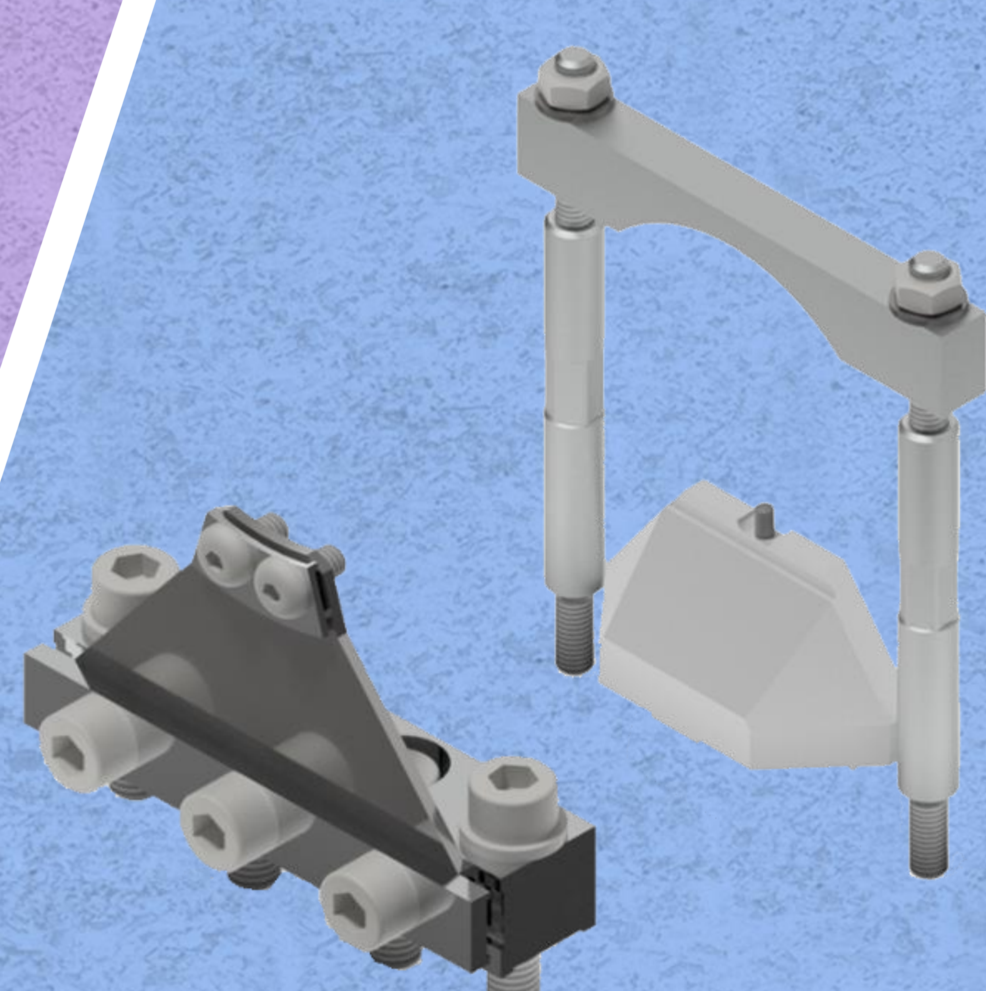
Microstructure of a FSW welded region.



Microhardness analysis of a FSW welded region (in units of micro-Vickers).

Support

Regarding the component's support, one of its sides is used as a stiff reference to guarantee the alignment of the component's aperture. Pre-load and a guide pin are used to create a fixed reference for the component. On the other side it is used an elastic support, which is deformable in order to accommodate possible machining misalignments while still constraining the necessary degrees of freedom. To achieve this behaviour, a thin sheet is applied as a flexure.



Front-end power absorbers' supports

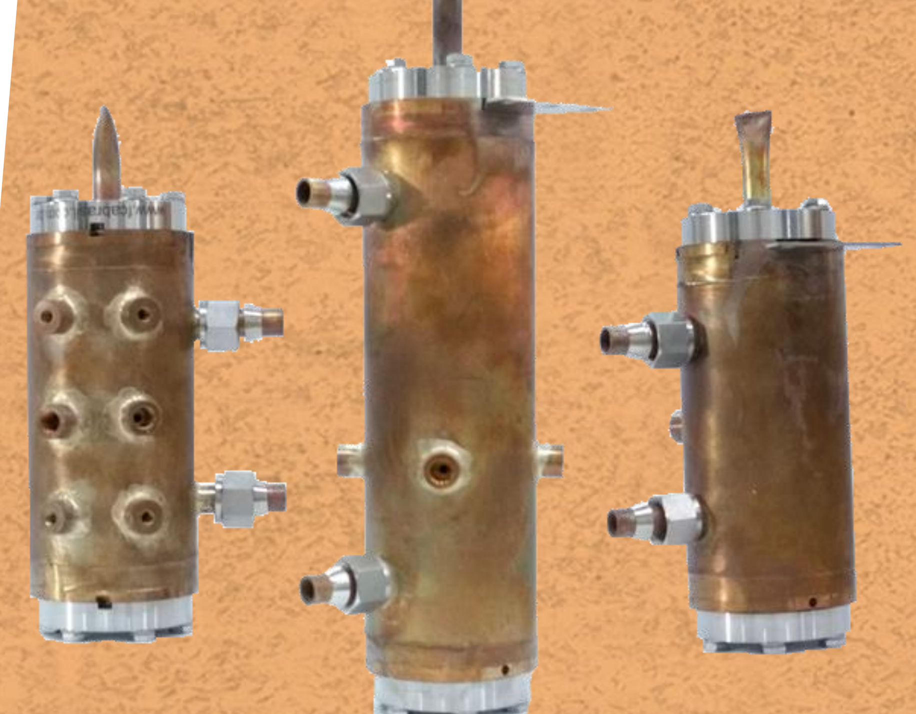
Tests and Validation

Leak Test:

- Components were approved for values of leak rate below 5e-10 mbar/(L·s);
- The operational pressure of those components will be 1e-10 mbar.

Hydrostatic Pressure Test:

- The tests were conducted for, at least, 3 hours ;
- Minimum test pressure of 15 bar;
- The operational water pressure of those components will be constant at 8 bar.



Front-end FSW-welded CuCrZr componentes ready to be installed

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